

Instruction Manual
72-310J

Compact
Potentiometers

Catalog No. 72-310 Series

Catalog No. 72-312 Series



James G. Biddle Co.

PLYMOUTH MEETING, PA. 19462

**Instruction Manual
72-3102J**

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FIGURE 1: Compact Millivolt Potentiometer Cat. No. 72-310-05, with Selector Switch Accessory Unit Cat. No. 72-990, Mounted on Gold-Plated Copper Connecting Links.

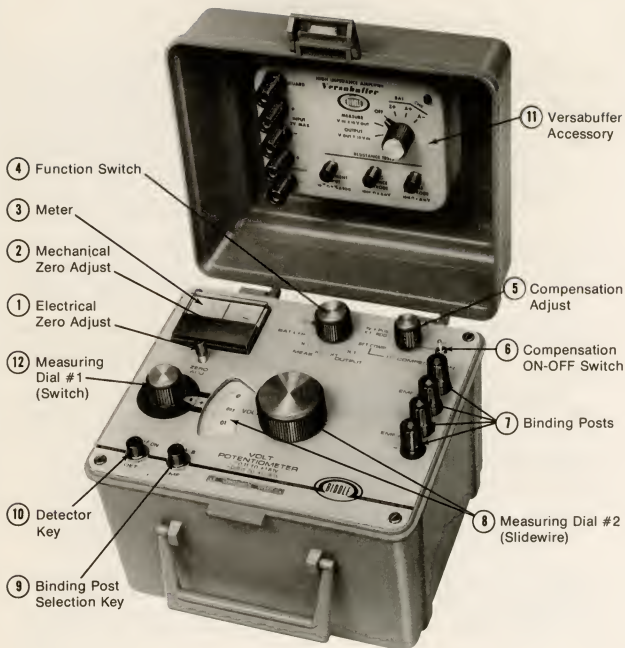


FIGURE 2: Compact Volt Potentiometer Cat. No. 72-312-03. (Composed of Cat. No. 72-312-01 with Versabuffer Cat. No.72-545 in Lid.)

SECTION A

INTRODUCTION

The Cat. No. 72-310-05 Compact Millivolt Potentiometer and Cat. No. 72-312-01 Compact Volt Potentiometer are portable general-purpose instruments having similar characteristics except for range. The Cat. No. 72-310-05 instrument measures millivolt inputs or develops known millivolt outputs in two ranges extending to 111 mV. The Cat. No. 72-312-01 instrument performs the same functions in two ranges extending to 1.61 volts. All ranges cross zero for ease of use on inputs of unknown polarity. Both potentiometers also feature manually set thermocouple reference junction compensation and a solid-state reference supply which never needs standardizing.

These instruments are used to calibrate recorders and controllers, and to measure emf's from thermocouples and other transducers. A special range having exceptional accuracy between 1.0 and 1.1 volts is used to calibrate standard cells and digital voltmeters.

The instruments are powered by zinc-carbon batteries, and since they do not use standard cells, they contain no mercury and can be used in locations where mercury is forbidden.

Several accessories are available to extend the usefulness of these instruments as outlined in Section F, "Applications". The accessories are as follows:

- . Cat. No. 72-542 Run-Up Box for calibrating deflection instruments.
- . Cat. No. 72-545 Versabuffer for testing pH and other high-resistance systems.
- . Cat. No. 72-990 input selector switch (6 inputs).
- . Cat. No. 72-910 Volt Box for voltage measurement to 1000 volts.
- . Cat. No. 72-920 Shunt Box for precision current measurements.

The accessory units can be built as integral parts of the instruments, as shown in Figure 2. These combinations are described in this manual, but separate instruction material is also supplied for each accessory. Four of these combinations are supplied as separate catalog numbers, as follows:

<u>CAT. NO.</u>	<u>DESCRIPTION</u>
72-310-06	72-310-05 with Cat. 72-542 Run-Up Box.
72-310-09	72-310-05 with Cat. 72-545 Versabuffer.
72-312-02	72-312-01 with Cat. 72-542 Run-Up Box.
72-312-03	72-312-01 with Cat. 72-545 Versabuffer.

SECTION B

SAFETY PRECAUTIONS

These instruments operate solely from dry batteries of low voltage and, therefore, meet the classification of "extra-low-energy source" (ANSI C39.5-1974, "Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation", Para. 3.) They do not present a shock hazard in themselves, but as with all electrical equipment, safety rules must be observed. Particular care should be taken that wires carrying high voltages or power are not connected to the instrument binding posts.

RECEIVING INSTRUCTIONS

Your Potentiometer has been thoroughly tested and inspected to rigid specifications before being shipped and is ready for use. Check the equipment received against the packing list. Notify James G. Biddle Co., Plymouth Meeting, Pa. of any shortage of materials. Examine for damage received in transit. If any damage is found, file a claim with the carrier at once and notify James G. Biddle Co. or its nearest representative giving a detailed description of the damages observed.

Before using the instrument, become familiar with its capabilities by scanning through this manual and making the Functional Checks listed in Paragraph G-1.

SECTION C

SPECIFICATIONS

1. RANGE, RESOLUTION, SENSITIVITY, LIMIT OF ERROR

CAT. NO. SERIES	RANGE (MEASURE & OUTPUT)	RESOLUTION	LIMIT OF ERROR	DETECTOR SENSITIVITY $\mu\text{V}/\text{DIV}$
310	-1.1 to 11.1mV	1 μV	$\pm(0.05\% \text{ of Rdg} + 5\mu\text{V})$	4
	-11 to 111mV	10 μV	$\pm(0.05\% \text{ of Rdg} + 20\mu\text{V})$	30
	+1 to 1.111V*	10 μV	$\pm(0.02\% \text{ of Rdg})$	30
312	-0.011 to 0.161V	0.01mV	$\pm(0.05\% \text{ of Rdg} + 0.02\text{mV})$	30
	-0.11 to 1.61V	0.1mV	$\pm(0.05\% \text{ of Rdg} + 0.2\text{mV})$	250
	+1 to 1.161V*	0.01mV	$\pm(0.02\% \text{ of Rdg})$	30

* This range has full accuracy for Output use if load resistance is $>20\text{M}\Omega$.

2. VOLTAGE REFERENCE AND SUPPLY

Type: Biddle Reliavolt $\text{\textcircled{R}}$ solid-state circuit.
 Battery requirement: 18V at approximately 6 mA.
 Long Term Stability: 0.01% per year.
 Temperature Coefficient: less than 0.0005% per C.
 Warmup Time: Within 0.002% of final value in 10 seconds.
 Regulation: Maximum voltage change of 0.002% from maximum battery voltage (19V) to minimum battery voltage (12V).
 Adjustment: Internal trimmer permits readjustment to $\pm 0.001\%$.

3. DETECTOR

Type: Taut band meter driven by solid state amplifier.
 Sensitivity: See table above. Meter has a 1-3/4" zero-center scale marked with 20 divisions. Deflection is linear.
 Input resistance: 5000Ω .
 Drift: $<1\mu\text{V}$ per hour at constant ambient temperature.
 Zero control: Adjustment range of $\pm 130\mu\text{V}$ to compensate for thermal emf's and long term drift.

4. INPUT OVERVOLTAGE TOLERANCE

± 35 volts continuous, without damage.

SPECIFICATIONS (CONT'D.)

5. REFERENCE JUNCTION COMPENSATOR

Manual ten-turn rheostat with a range of -1.5 to +3.5 mV and resolution of 2 microvolts. Compensation can be made within an ambient temperature range of -15°F to +135°F (-26°C to +57°C). Setting is stable with both time and temperature change. May be switched on or off; functions in all ranges except "1V+POS RDG".

6. OPERATING TEMPERATURE RANGE

-20°F to +140°F (-29°C to +60°C)

7. BATTERY REQUIREMENTS

CIRCUIT	VOLTAGE	QTY	TYPE	MINIMUM LIFE
Measuring	9V	2	Burgess M6 or Eveready 266 (NEDA 1605)	430 hours
Compensator	1½V	1	"C" Cell	2000 hours
Null Detector	9V	2	Burgess 2U6 or Eveready 216 (NEDA 1604)	430 hours

8. SAFETY

Meets applicable requirements of ANSI C39.5-1974, "Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation".

9. ENCLOSURE

Instrument is fully enclosed in field case with carrying handle and hinged lid. Top panel is aluminum with a PVC acrylic plastic overlay. Case is fire-resistant high-impact ABS plastic with gray texture finish. Lid is removable and contains storage compartment for instruction manual, leads, etc.

10. DIMENSIONS AND WEIGHT

9" x 7½" x 7½" high (23 x 19 x 19 cm); 5.5 lbs. (2.5 kg).

SECTION D

DESCRIPTION

1. GENERAL

The Catalog Nos. 72-310 and 72-312-02 potentiometers combine measuring circuitry, detector, and power source in a self-contained portable package. Circuitry is simple and rugged, and utilizes highly reliable components for long, trouble-free service.

The instrument panel and carrying case are made of materials which are both flame-retardant and chemical resistant.

The lid of the instrument case is fitted with a hinged compartment cover, with latch, which holds the instruction manual and will accommodate test leads, thermocouples, etc.

2. CONTROLS AND CONNECTORS

The operating controls are shown in Figures 1 and 2. Their functions are described in the following list.

(a) FUNCTION SELECTOR SWITCH

Permits selection of one of the following functions:

OFF - shorts the meter and disconnects the amplifier, batteries, and binding posts.

BAT CHK - sets the instrument to indicate the state of charge of the constant voltage supply battery on the meter.

MEAS X.1 - sets the instrument for measurement on the low range.

MEAS X1 - sets the instrument for measurement on the high range.

OUTPUT X1 - connects a calibrated high range voltage to the binding posts when the DET key is depressed; disconnects the detector from the circuit.

OUTPUT X.1 - connects a calibrated low range voltage to the binding posts when the DET key is depressed; disconnects the detector from the circuit.

SET COMP - permits setting of the reference junction compensator when the TC COMPENSATION switch is on.

1V+POS RDG - sets the instrument for high precision measurement in a range of 1 to 1.1+volts.

(b) MEASURING DIALS (Items 12, 8, in Figure 2)

The measuring dials consist of a decade step switch and a slidewire with scale. The slidewire covers one step of the decade switch with 10% overlap.

DESCRIPTION (CONT'D.)

(c) MANUAL REFERENCE JUNCTION COMPENSATOR CONTROLS

The compensator controls consist of an ON-OFF switch (Item 6, Figure 2) and a ten-turn rheostat (Item 5, Figure 2).

(d) BINDING POSTS AND SELECTOR KEY

Two pairs of binding posts (Item 7, Figure 2) provide input/output connection. A two-position key (Item 9, Figure 2) selects one of the pairs.

(e) DETECTOR KEY (Item 10, Figure 2).

The detector key, when depressed, connects the binding posts to the circuitry and, in the Measure and Set Comp modes, connects the detector to the measuring circuit (opening a short circuit). A clockwise turn locks the key down.

(f) ZERO ADJUST CONTROL

May be adjusted to compensate for internal drift or external offsets.

3. CIRCUIT DESCRIPTION (Refer to appropriate schematic diagram, Figure 13 or 14, and to the simplified schematic, Figure 3).

The Reliavolt constant voltage supply provides reference voltage and current (0.55 mA for the Cat. No. 72-310 and 2.75 mA for the Cat. No. 72-312) to the measuring circuit. It maintains this value over extremes of battery voltage and operating temperature.

When the Function Selector Switch is in the MEAS X1 or OUTPUT X1 position, the reference current divides in a 10:1 ratio with the larger portion flowing through the step-switch and slidewire, and the smaller portion being shunted through the branch circuit. When the Function Selector switch is in the MEAS X.1 or OUTPUT X.1 position, the reference current divides in a 1:10 ratio with the small portion flowing through the step-switch and slidewire, and the larger portion being shunted through the branch circuit. The step switch has a minus (-) position for reversing the voltage polarity of the slidewire.

The reference junction compensating voltage is precisely set by utilizing the emf measuring dials as a reference.

DESCRIPTION (CONT'D.)

The null detector, consisting of a carefully selected operational amplifier driving a rugged zero-center meter, indicates a "null balance" or zero deflection when the measuring circuit emf is equal to an emf introduced at the instrument binding posts.

When the Function Selector Switch is set to OUTPUT it short-circuits the null detector input, and the emf of the measuring circuit appears at the selected binding posts when the DET key is down.

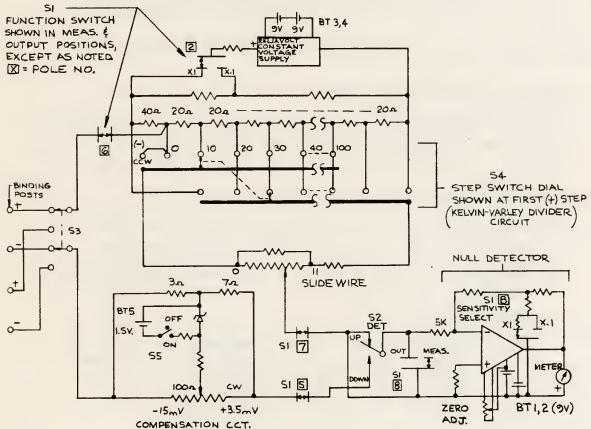


FIGURE 3: Simplified Schematic of Potentiometer in Measure and Output Modes (Values Given for Millivolt Version)

SECTION E

OPERATION

TO SAVE BATTERY, TURN OFF WHEN NOT IN USE
--

Proceed with steps 1 and 2 (below) before using the MEASURE function, and Step 1 before using the OUTPUT function. If the Potentiometer has been out of service for some time, operate all the controls a few times and make the Function Checks listed in Paragraph G1.

In adjusting for a null, clockwise rotation of any control moves the needle to the right, and vice versa.

1. Measuring Circuit Battery Check

Rotate the Function Selector Switch to BAT. CHK. If the meter pointer does not reach the green zone, replace measuring circuit batteries. (See Section G.)

2. Meter Zero Adjustment

- (a) With the Function Selector at the OFF position, adjust the meter to "0" by turning the screw in the meter cover.
- (b) Rotate the Function Selector to one of the MEAS positions or COMP SET, and rotate the ZERO ADJ. rheostat to bring the meter pointer to "0".

NOTE: When the pointer cannot be adjusted to "0" or the detector sensitivity is significantly less than normal, replace the amplifier batteries. (See Section G.)

OPERATION (CONT'D.)

3. Measuring an emf without TC Compensation

To measure an external emf, proceed as follows:

- (a) Set the TC Compensation switch off.
- (b) Connect the emf to be measured to the desired emf binding posts (A or B) using copper wire and observing proper polarity.
- (c) Set the Binding Post Selector Switch to position A or B corresponding to the emf binding posts in use.
- (d) Set the Function Selector Switch to the appropriate MEASURE position.
- (e) Adjust the meter zero if required, as described in Section E2.
- (f) Rotate the emf measuring dials to the probable voltage value. If the approximate value of emf to be measured is unknown, set the measuring dials to the maximum setting.
- (g) Depress the DET key and note the direction of the meter pointer deflection. Adjust the measuring dials until a meter null is reached, first making a coarse setting on the step switch, and then a fine setting on the slide-wire. For the best precision, release and depress the DET key, adjusting the slide-wire until no meter movement is visible as the key is moved.
- (h) Read the measured emf by adding the step switch reading to the slide-wire reading, and applying the indicated multiplier.

NOTE: If the meter pointer deflects to the right when the two emf measuring dials are set at their "0" position, the measured emf has negative polarity. Rotate the step switch to the minus (-) position and adjust the slide-wire dial for null. Record negative polarity for any readings made in this way.

If the balance cannot be reached in the negative (-) range, the input connections must be interchanged.

OPERATION (CONT'D.)

4. Reference Junction Compensation Adjustment

This compensation is used in temperature measurements with a thermocouple and in checking thermocouple meters and recorders. It compensates for the voltage of the thermocouple reference junction and must be adjusted to match the temperature existing at the reference junction when the actual measurement or check is made.

To set the reference junction compensator, proceed as follows:

- (a) Rotate the Function Selector Switch to the SET COMP position.
- (b) Adjust the meter pointer to electrical "0", if required, as described in Section E2.
- (c) Measure the temperature of the thermocouple reference junction with an accurate mercury-in-glass thermometer. The reference junction is the point of connection between the dissimilar metal thermocouple wires and copper wire. This is usually at the instrument binding posts. (See Figure 4).
- (d) Obtain the equivalent millivolts by referring to the appropriate table in Temperature-Millivolt Conversion Table, Biddle Publication Number 60-35T (or NBS Monograph 125).
- (e) Set this emf on the measurement dials, using the X.1 multiplier. Set the step switch to "0" for positive polarity emf and to (-) for negative polarity.
- (f) Switch the TC COMPENSATION switch to the ON position. Depress the DET key and adjust the TC COMPENSATION rheostat to null the meter.

The compensator is now at the correct emf value and will be connected in the measuring circuit when the Function Selector switch is in any position except 1V+POS RDG. However, if the temperature at the reference junction changes, the compensator must be reset accordingly.

OPERATION (CONT'D.)

5. Measuring a Thermocouple emf, Using TC COMPENSATION

- (a) Connect the thermocouple to the desired emf binding posts (A or B) observing proper polarity. Note that thermocouple leads are color-coded red for negative polarity.
- (b) Set the compensation according to the thermocouple being used and the temperature of the reference junction, as described in paragraph E-4.
- (c) Leave the TC COMPENSATION switch ON and measure the emf of the thermocouple as in paragraph E3, starting at step (c).
- (d) Convert the measured emf to temperature, using the temperature millivolt table for the type of thermocouple being used.

6. Use of Output Mode

The Output mode is used for simulating sources of emf such as thermocouples and for calibrating instruments which measure emf. To provide a calibrated emf output in the normal instrument range, proceed as follows:

- (a) Set the Function Selector Switch to an Output position.
- (b) Depress the DET key.

The emf of the measuring dials now appears at the selected pair of binding posts.

Further details are given in Section F, "Applications".

TURN OFF WHEN NOT IN USE.

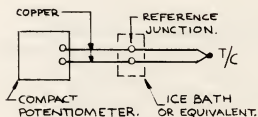
SECTION F

APPLICATIONS

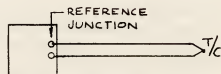
1. NOTES ON TEMPERATURE MEASUREMENT

The output of a thermocouple is actually two separate emf's in series: one at the measuring junction and one at the reference junction. The standard tables, such as Biddle Publication #60-35T, or NBS Monograph 125, give the net emf's of the series pair over the full range of measuring junction temperatures, with the reference junction temperature held at 0°C (32°F).

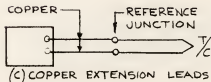
To obtain a true temperature at the measuring junction by using the tables, then, one can hold the reference junction temperature at 0°C , and measure the emf; the desired temperature is then obtained directly from the tables, since this procedure is the same one as was used in making up the tables. This procedure is illustrated in Figure 4 (a).



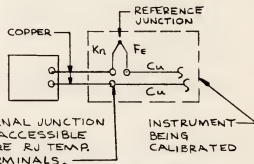
(A) USING ICE BATH;
NO COMPENSATION REQUIRED.



(B) T/C WIRE DIRECT TO POT



(C) COPPER EXTENSION LEADS



(D) CALIBRATING AN INSTRUMENT WHICH HAS INTERNAL RJ COMPENSATION.

FIGURE 4: Various Thermocouple Connection Diagrams, Showing Location of Reference Junction.

APPLICATIONS (CONT'D.)

1. NOTES ON TEMPERATURE MEASUREMENT (Cont'd.)

When an ice bath or equivalent is not used, the temperature and resulting emf of the reference junction must be taken into account. The emf can be read directly from the temperature-emf tables using the temperature measured at the reference junction. The correction is made by algebraically adding this emf to the potentiometer reading. The corrected emf is used in finding the measuring junction temperature from the tables. Figure 4, (b) and (c), illustrate this arrangement.

To make this correction easier, the compact volt and millivolt potentiometers provide a feature called manual reference junction compensation. The reference junction emf is obtained as before using thermometer and tables, and this emf is stored in the instrument. The emf correction is automatically included in the final reading. This eliminates a mathematical operation; this feature is especially useful when making a series of readings where the temperature at the reference junction is not changing appreciably; a single setting of the compensator makes the correction for the entire series of readings. The compensation procedure is outlined in Section E, and may be used in the cases (b), (c), and (d) of Figure 4.

The location of the reference junction is not always obvious. The reference junction may be defined as the junction of the thermocouple wire with copper or equivalent (which is used in the potentiometer. Actually, the junction usually consists of two junctions side-by-side, in which case these junctions should be close together so that a single measured temperature will hold for both connections. The location in various cases is shown in Figure 4.

APPLICATIONS (CONT'D.)

2. CHECKING THERMOCOUPLES

In order to check a thermocouple, some means of maintaining the measuring junction of the thermocouple at a known temperature is required. The procedure for reading the thermocouple at the known temperature is the same as previously described in Section E5.

A typical arrangement using a reference thermocouple is shown in Figure 5. Note the convenience of using the dual input terminals of the potentiometers.

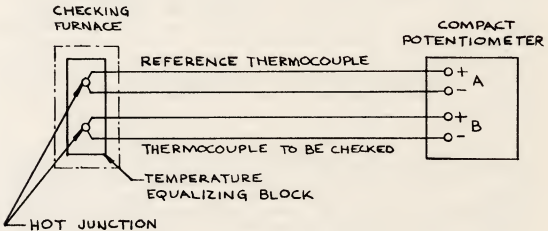


FIGURE 5: Checking a Thermocouple Against a Reference Thermocouple

APPLICATIONS (CONT'D.)

3. MEASURING FROM SEVERAL EMF SOURCES

Up to six (or more) emf sources can be quickly measured by using the Catalog No. 72-990 Thermocouple Selector Switch Accessory Unit. (Shown in Figure 1).

It is provided with two gold-plated copper links for low thermal emf connection to the potentiometer.

Connect the POT binding posts of the Cat. No. 72-990 Selector Switch to the desired (A or B) binding posts of the measuring potentiometer using the links or copper wire. Observe polarity of all connections. One to six inputs may be connected to the pair of thermocouple binding posts located on the Cat. No. 72-990 accessory which may then be selected by the rotary switch for connection to the instrument for measurement.

Up to twelve inputs can be handled by using a second Selector Switch connected to the second pair of TC binding posts.

If the measured emf's are from thermocouples, the reference junction is located at the thermocouple terminals on the switch.

4. CALIBRATING POTENTIOMETERS AND OTHER HIGH-IMPEDANCE INSTRUMENTS

This section applies to calibration of instruments having input resistance above 1 megohm. Such instruments do not appreciably load the potentiometer when it is used in the Output mode. The following types of instruments are in this category:

- . Potentiometers, manual or self-balancing.
- . Digital instruments.
- . Electronic (analog) process controllers.
- . Analog-to-Digital converters.

APPLICATIONS (CONT'D.)

4. CALIBRATING POTENTIOMETERS (Cont'd.)

The following calibration procedure applies to instruments having either compensated (for TC reference junction) or uncompensated ranges:

- (a) Connect the instrument to be checked to the desired emf binding posts (A or B) using copper wire and observing proper polarity.
- (b) Set the Binding Post Selector Switch to position A or B corresponding to the emf binding posts in use.
- (c) This step is for TC compensated instruments only. Set compensation according to the thermocouple type as described in paragraph E-4. See Figure 4 (d) for location of reference junction. Leave the TC Compensation switch ON.
- (d) Rotate the Function Selector Switch to the appropriate OUTPUT position.
- (e) Rotate the emf step switch and slide-wire to the desired emf setting. If the range being checked is in temperature, use the emf equivalent of the desired temperature check point (obtained from tables).
- (f) Depress and lock down the DET key.
- (g) Observe the reading of the instrument being checked.
- (h) If desired, repeat the above procedure at various test settings to obtain a series of correction factors.

NOTE: In checking manual balance potentiometers it is generally more convenient to set the instrument to be checked to the selected test setting and read the true emf value directly on the measuring potentiometer in the Measure mode. Set the instrument under test to the Output position; if none is available, and detector interaction is observed, short circuit the detector of the instrument being checked.

APPLICATIONS (CONT'D.)

5. CALIBRATING DEFLECTION MILLIVOLTMETERS AND OTHER LOW-IMPEDANCE INSTRUMENTS

Deflection type instruments and other instruments having input resistance less than about 1 megohm require the use of a millivoltage source which will deliver the current required. Biddle supplies the Cat. 72-542 Run-Up Box for this purpose, either as a separate accessory or mounted in the lid of the Potentiometer.

To use the Run-Up Box, connect as shown in Figure 6 and proceed as follows:

- Determine the external resistance (source and lead) normally seen by the instrument being checked and set the Lead Resistance control of the Run-Up Box to this value.
- Set the appropriate range and adjust the Run-Up control to obtain the desired indication on the instrument being checked.
- Balance the Potentiometer in the Measure mode, using the compensation as indicated in Section D-5 if the instrument being checked is internally compensated. It now indicates the actual input to the instrument being checked. To find the instrument correction, subtract the instrument reading from the Potentiometer reading. Repeat for as many points as desired.

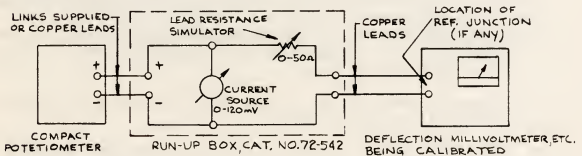


FIGURE 6: Schematic of Run-Up Box Accessory Connected for Calibrating a Deflection Instrument.

APPLICATIONS (CONT'D.)

6. PRECISION READINGS OF STANDARD CELLS AND OTHER 1-VOLT REFERENCE SOURCES

The compact potentiometers have a special range with exceptional accuracy for calibrating these reference devices; the range is 1.0 to 1.1110 volts (1.0 to 1.1610 on the Volt pot). In checking standard cells care must be taken to avoid current flow, as in the following procedure:

- (a) With the DET key up, connect the standard cell to the desired emf binding posts (A or B) using copper wire and taking special care to observe proper polarity.
- (b) Set the Binding Post Selector Switch to position A or B corresponding to the emf binding posts in use.
- (c) Rotate the Function Selector Switch to the 1V + POS RDG position.
- (d) Adjust the detector to electrical zero, if required, as described in Section E-2.

- (e) Note the nominal value marked on the standard cell. Subtract 1.0000 volts from this value and enter the difference on the emf measuring dials. For example:

Cell nominal: 1.01920 volts

Subtract 1.000: 0.0192 volts, or 19.20 mV

Set: On Millivolt Pot, switch to 10 mV, slidewire to 9.20 mV.

On Volt Pot, switch to 0.1, slidewire to 0.0920 volts.

- (f) Tap the DET key and note the meter pointer deflection. If the deflection is to the right, the emf dial settings are too high; if to the left, too low.
- (g) Increase or decrease the setting of the slide-wire as dictated by step (f) and adjust for null.
- (h) The potentiometer now reads the emf of the standard cell with an accuracy of ± 0.2 mV. Since no current is drawn from the voltage source by the potentiometer, no measuring error is introduced.

APPLICATIONS (CONT'D.)

Reference devices other than standard cells, such as Zener regulators, can be read without the special precautions to avoid loading.

For a nominal voltage of exactly one volt, values below nominal cannot be read directly because the (-) position of the emf step switch does not function in the 1V + POS range. However, if the actual voltage is above 0.9995 volts (within 0.5 mV below 1 volt) it can be read by calibrating the null detector. To reach the full 0.5 mV, the detector zero must be set at the left end of the scale rather than the center; then readings to the right of this point when the measuring dials are both at zero should be subtracted from 1.0000 volts to obtain the reading. The meter calibration is made by comparing meter deflection to the slide-wire movement, and is usually between 25 and 30 microvolts per meter division.

7. PRECISION CALIBRATION OF DVM's AND OTHER HIGH IMPEDANCE INSTRUMENTS AT ONE VOLT

The 1 volt + POS range is a measuring range, but it can also be used with full accuracy of 0.02% as a source for calibration of instruments having an input resistance of 20 megohms or more. Any potentiometer or digital voltmeter meets this requirement as do many other electronic instruments.

The detector is not disconnected from the circuit on this range as on true OUTPUT ranges, and some detector interaction may be observed when supplying an emf to another potentiometer. The meter pointer will return to "0" when the second instrument is truly at balance.

NOTE: Current drawn from the Potentiometer before a null balance-type instrument being calibrated reaches balance will not affect the final accuracy of the output voltage. Recovery from such loading is instantaneous.

APPLICATIONS (CONT'D.)

8. CALIBRATING pH AND ORP INSTRUMENTS WITH THE VOLT POT

The Volt Potentiometer has a range of 1.6 volts covering the entire range used in pH and oxidation-reduction potential (ORP) measurements. It is an excellent source for calibrating the receiving instruments or pre-amplifiers used for these measurements, using the procedure of Section F-4. A series resistor can be added in the output and the change in receiver reading can be used to calculate the input resistance of the receiver.

The Volt Pot can also read the output of the ORP cells. There is some loss of sensitivity due to the high resistance of the cell but for cells of up to 100,000 ohms, readings can be made to 2 mV or better.

ORP cell resistance can be calculated by the following procedure:

- (a) Note the null balance setting of the measuring dials.
- (b) Move the dials either way for a full scale meter deflection.
- (c) Subtract reading (b) from reading (a).
- (d) Calling the difference obtained in (c), in volts, " ΔE " the cell resistance, R_s is:

$$R_s = 2 \times \Delta E, \text{ in megohms}$$

pH cells cannot be measured directly with the Potentiometer, because of their very high resistance. These measurements, however, can readily be made using the Versabuffer accessory with either the Volt Pot or Millivolt Pot. (See paragraph F9 which follows.)

APPLICATIONS (CONT'D.)

9. TESTING AND TROUBLESHOOTING pH AND ORP SYSTEMS

Complete testing of these cells and related instruments can be accomplished using a compact Pot and the Biddle Cat. No. 72-545 Versabuffer accessory module. The Versabuffer is shown in Figure 2 and is fully described in a separate instruction manual. It provides convenient features for both voltage calibration and resistance tests.

In the measuring mode, shown below in Figure 7, the Versabuffer functions as a high-impedance unity-gain voltage follower whose output is attenuated by a factor of ten to provide a millivolt output from a voltage input. Pushbuttons inject test currents for making cell resistance tests. In the output mode the Versabuffer functions as an isolation amplifier with a gain of ten, capable of directly driving all pH instruments. The following tests can be made:

- . Measurement of the output of pH and ORP cells and other high resistance sources.
- . Calibrating pH and ORP indicators, recorders and controllers.
- . Measurement of pH or ORP cell electrode resistance.
- . Measurement of instrument preamplifier input resistance.

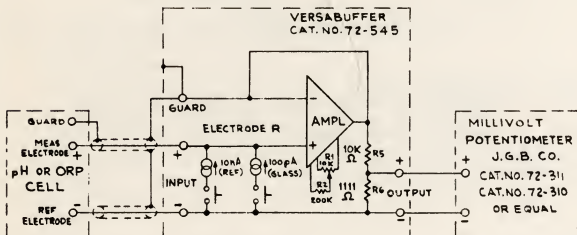


FIGURE 7: Measuring emf of pH & ORP Cells,
(Versabuffer in Measure Mode.)

APPLICATIONS (CONT'D.)

10. MEASUREMENTS TO 1000 VOLTS USING THE VOLT BOX ACCESSORY

The Cat. No. 72-910 Volt Box extends the measurement range of the potentiometer to 1000 volts. Combined limit of error is 0.1% of reading, equivalent to a 4-digit DVM. The connections are shown in Figure 8. Further details are given in the Instruction Sheet supplied with the Volt Box.

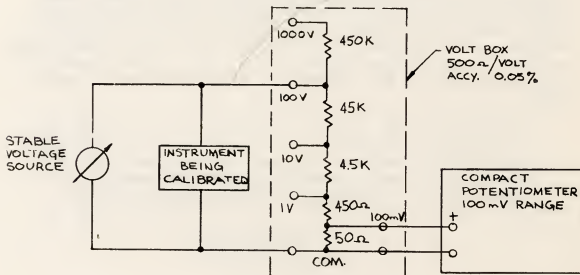


FIGURE 8: Schematic of Cat. No. 72-910 Volt Box Connected for Calibrating a DVM or other Instrument in the 0-100 Volt Range.

APPLICATIONS (CONT'D.)

11. DC CURRENT CALIBRATION USING THE SHUNT BOX ACCESSORY

The Cat. No. 72-920 Shunt Box adapts the Potentiometer to measurement of DC current up to 1 ampere with a sensitivity of 1 microampere. Ranges of 10, 100, and 1000 mA provide 100 mV output; using the 10 mV range of the Millivolt Pot, ranges down to 1 mA are available. Overall accuracy is $\pm 0.1\%$ of reading on all ranges.

Connections are shown in Figure 9. Further details are given on the Instruction Sheet supplied with the Shunt Box.

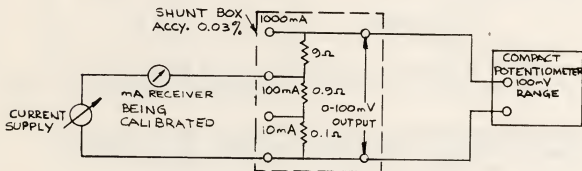


FIGURE 9: Schematic of Cat. No. 72-920 Shunt Box
Connected for Calibrating a 4-20 mA Process Control Unit

12. RESISTANCE AND RESISTANCE THERMOMETER MEASUREMENTS

The Potentiometer, because it draws no current at null, is the ideal instrument for precision low resistance measurements. Lead resistances of hundreds of ohms cause no error.

In this method, the unknown is compared to a known reference resistor by passing a current through both resistors in series and measuring the voltage across each, taking advantage of the convenient dual input terminals of the potentiometer. As shown in Figure 10, a stable, preferably adjustable, current supply is required.

Best accuracy of $\pm 0.02\%$ is obtained if both resistors are of the same order of magnitude, say within 2 to 1, and if both voltage drops fall in the upper part of one potentiometer range.

APPLICATIONS (CONT'D.)

12. RESISTANCE MEASUREMENTS (Cont'd.)

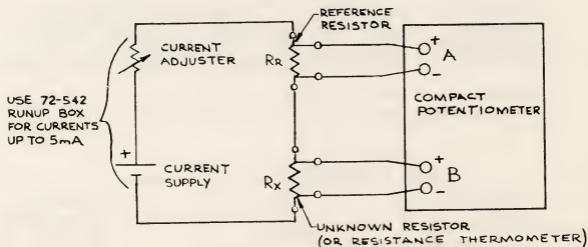


FIGURE 10: Measuring an Unknown Resistance by Comparison to a Known Reference Resistor. The Cat. No. 72-920 Shunt Box is an Excellent Reference Resistor; a Large Dry Cell Supplies Currents up to 1A.

Range of Measurements:

Upper limit = $10,000\Omega$, because of detector limitations.

Lower limit = $1\mu\Omega$ (Using the 11-mV range of the Millivolt Pot, with a current of 1A, a change of about $1\mu\Omega$ can be detected.)

Using the 72-920 Shunt Box as a 4-wire reference resistor, (See Section F-11) a range of about $1m\Omega$ to 100 ohms can be covered with currents of 1 ampere or less.

Using the Cat. No. 72-910 Volt Box (See Section F-10) as reference resistor, a range of 10 ohms to 10,000 ohms can be covered with currents of 10 milliamps or less. The resistors of the Volt Box have an accuracy of $\pm 0.02\%$. Four-wire connections can be made on the 50Ω and 500Ω values, connecting the potentiometer to one step above the current connections; on higher values this should not be done and is not necessary.

APPLICATIONS (CONT'D.)

12. RESISTANCE MEASUREMENT (Cont'd.)

A convenient procedure is the following:

- (a) Determine the approximate current to be used based on the resistor ratings, the current available, and the potentiometer ranges available. Compute the expected voltage across the reference resistor. Connect as in Figure 10.
- (b) Set the Selector Switch to binding posts A. (reference resistor).
- (c) Set the Function Selector Switch to the appropriate MEASURE range.
- (d) Set the Measuring Dials to the expected setting.
- (e) While tapping the DET key, adjust the current adjusting rheostat or adjustable current supply to obtain, as nearly as possible, a null meter balance.
- (f) Depress the DET key and readjust the slide-wire to obtain a final balance. Record the reading as V_R .
- (g) Select binding posts B, the unknown resistor.
- (h) While tapping the DET key, adjust the Measuring Dials to obtain a balance. Record the reading as V_X .
- (i) Check the V_R reading again to make sure that the current has remained stable. This is especially important when reading a resistance thermometer to measure temperature, as any changes in its resistance due to change in temperature may change the current.
- (j) Find the value of the unknown resistor from the following equation:

$$R_X = \frac{V_X}{V_R} R_R$$

If the value of the unknown, R_X , is close to the value of the reference R_R , the ratio accuracy is within 0.02%.

APPLICATIONS (CONT'D.)

13. VOLTAGE DIVIDER RATIO MEASUREMENT

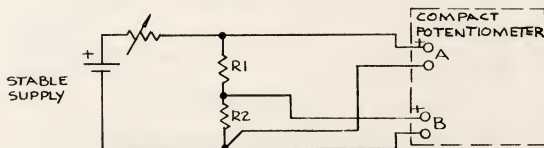


FIGURE 11: Measuring the Divider Ratio $\frac{R_2}{R_1 + R_2}$

The Potentiometer Draws No Current at Null,
so the Measurement Does Not Load the Divider.

This is an excellent way to check the linearity or conformity of a potentiometer to 0.03%, or to check the ratio of fixed dividers. Full accuracy is obtained for values of $R_1 + R_2$ up to 10,000 ohms.

With the connections as shown in Figure 11, proceed as follows:

- Adjust the current for a voltage near full range across $R_1 + R_2$ (V_A).
- Measure V_A and V_B .
- The voltage divider ratio is:

$$\frac{R_2}{R_1 + R_2} = \frac{V_B}{V_A}$$

APPLICATIONS (CONT'D.)

14. USING THE POTENTIOMETER AS A NULL DETECTOR

To use the potentiometer as a 5000-ohm null detector, with sensitivity as listed in Section C, proceed as follows:

- (a) Set both measuring dials to zero.
- (b) Set the Function switch to Measure X1 or X.1 according to sensitivity desired.
- (c) Short circuit input A and connect the circuit being measured to input B.
- (d) Select input A and, holding down the DET key, adjust the ZERO ADJUST control for zero reading of the meter.
- (e) Switch to input B and proceed to measure. To calibrate the deflection, note the slide-wire change which changes the meter reading by 5 or 10 divisions.

15. AC, OSCILLOSCOPE AND OTHER ELECTRONIC CIRCUIT APPLICATIONS

In sensitive electronic circuits, the portable Pot has some special advantages:

- (a) It is completely floating and has low impedance so it can be used anywhere in the circuit without introducing noise.
- (b) It is more accurate and sensitive than the usual electronic test gear, and provides a calibrated output.

Some useful applications are:

- Improving oscilloscope accuracy by 10 or more for dc or pulses.
- AC current measurement using Shunt Box and Oscilloscope.
- DC or pulse amplifier gain measurement.

These and others are shown in Biddle publication #72-50 entitled "Practical Potentiometry" which is available on request.

SECTION G

MAINTENANCE

1. FUNCTIONAL CHECKS

The following simple checks will determine whether the instrument is in working order. Make them when the unit is first received, when removing it from storage, before taking it out for field use, and after all maintenance. Make tests in the order listed below. If any test is failed, repairs are needed.

- (a) Setup:
Set Compensation OFF, DET and emf keys up; short the emf "A" binding posts with a penny. If the instrument has been out of service for some time, rotate the measuring dials and controls several times over their full travel.
- (b) Measuring Circuit Battery Check:
Set Function Switch to BAT CHK position. Meter should indicate in the green band. If not, replace the measuring circuit batteries.
- (c) Zero Adjustment Check:
Switch to low Measure range and rotate ZERO ADJ control slightly; meter should respond. Adjust to 0. If meter remains pinned or does not respond, replace amplifier batteries.
- (d) Sensitivity Check, Millivolt Pot:
Set Measuring dials to 0.
Set emf selector key to A.
Depress DET key and lock down.
Move slide-wire to 0.4; meter should read near 10 right.
Move step switch dial to (-); meter should read near 10 left.
Repeat on high range with slide-wire at 0.3. If this test fails (indicating poor sensitivity) replace the amplifier batteries.
- (e) Sensitivity Check, Volt Pot:
Proceed as in (d), except set slide-wire to 0.03 and 0.025.
- (f) TC Compensation Check:
Turn TC COMP control full clockwise, and set switch ON.
Balance the measuring dials; reading should be between 3.5 and 4.2 millivolts and stable; if not, replace compensator battery.

MAINTENANCE (CONT'D.)

2. ROUTINE MAINTENANCE

With normal use the only routine maintenance required will be the functional checks, battery replacement and calibration check. These should be made annually on a formal basis. The first two should be made more frequently if usage is heavy.

After long periods of disuse it may be necessary to clean the slide-wire or push keys. This and other maintenance and calibration procedures are described in the following paragraphs. Refer to Figure 12 for location of internal components.

3. REMOVAL OF POTENTIOMETER FROM CASE

- (a) Remove the four panel screws and carefully lift the instrument from the case. The panel may be inverted in the case which will serve as a convenient holding fixture while maintenance is being performed.
- (b) Replace the Potentiometer in the case by reversing the procedure described above.

4. BATTERY REPLACEMENT

- (a) Measuring the circuit batteries:
Remove discharged batteries by removing 2 screws from the bottom of the component bracket and sliding the battery package out. Replace the two 9-volt batteries (Eveready #266, NEDA type 1605).
Packing should be replaced as originally found.
- (b) Amplifier batteries:
Remove batteries and replace with 2 fresh 9-volt batteries (Eveready #216, NEDA-1604). If this fails to produce correct zero adjustment, see step 7, below.
- (c) Compensator Battery:
Remove from clamp holders and replace with one "C" cell.

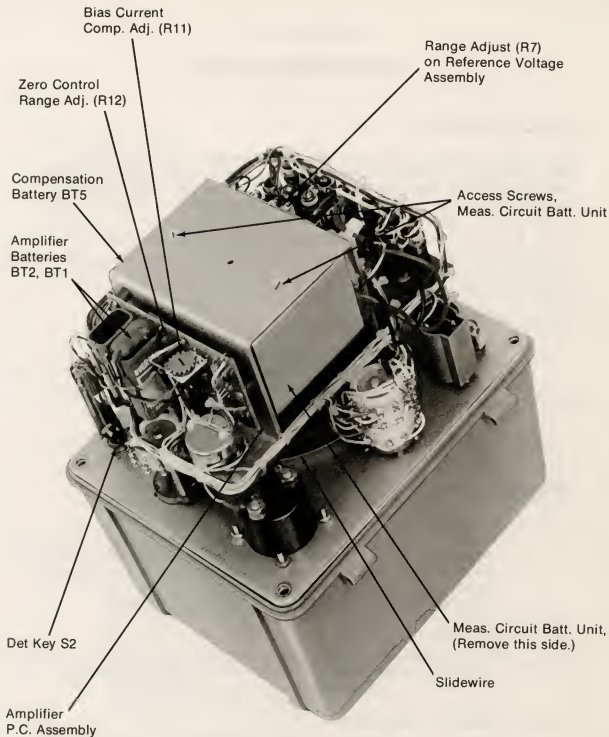


FIGURE 12: Internal View of Cat. No. 72-310-05. Cat. No. 72-312-01 is the Same Except Resistors R11 and R12 are Omitted.

MAINTENANCE (CONT'D.)

5. CLEANING SLIDE-WIRE

The need for slide-wire cleaning is indicated by erratic deflection of the meter produced by slow rotation of the slide-wire near null in the Measure mode.

- (a) Clean slide-wire surface by rubbing briskly with a soft cloth moistened with naphtha chloroethylene, benzene, alcohol or other volatile petroleum solvent. Dry with soft cloth sparingly impregnated with petroleum jelly or white vaseline.
- (b) On severely oxidized slide-wire not cleanable by step (a) above, polish gently with crocus cloth uniformly over the entire length of the slide-wire, then repeat step (a) above.

Care must be taken not to nick or dent the slide-wire winding while performing the above operations.

6. CLEANING PUSH KEY (DETECTOR AND INPUT SELECTOR)

Failure of the push key to make contact will be indicated by the failure of the meter to deflect when an unbalance is known to exist.

Key contacts may be cleaned by inserting a thin strip of bond paper or business card between the contacts and applying pressure to the contacts by depressing or releasing the key button as required while withdrawing the paper. Repeat three or four times, as necessary.

7. COMPENSATING FOR LONG-TERM DETECTOR DRIFT (72-310 SERIES)

It may be necessary to readjust the amplifier zero balance circuit to compensate for long-term drift changes beyond the range of the ZERO ADJ control. At the same time it is convenient to check and adjust the amplifier bias current. If the meter pointer cannot be adjusted to "0" and the batteries are known to be good, remove panel assembly from case and proceed as follows:

- (a) Short circuit the "A" binding posts with a piece of copper wire and connect a carbon or other low-thermal-emf resistor having a value between 2K and 4K ohms across the "B" binding posts.

MAINTENANCE (CONT'D.)

- (b) Set the function selector switch to MEAS X.1 and the binding post selector key to A.
- (c) With the DET key up, rotate the ZERO ADJ control through its full range while observing the meter pointer. If necessary use MEAS X1 range to keep the pointer on scale. The pointer should normally deflect approximately the same in both directions.
- (d) If the pointer range found in step (c) is offset, set the ZERO ADJ control to its mechanical center position and adjust R12 (See Fig. 12) to bring the meter pointer to within 1 division of "0"; then adjust ZERO control for exact "0". If the pointer can not be brought to "0", see step (g).
- (e) Depress the DET key and adjust the emf measuring dials for a null balance. Balance is indicated when there is no meter deflection on operation of the DET key.
- (f) Lock down the DET key, and depress the binding post selector key to position "B". If the change exceeds 1/4 division, adjust bias current trimmer, R11, so that there is no change in meter deflection while depressing and releasing the binding post selector key.

NOTE: There is some interaction between the adjustments of the R12 and the R11 trimmers. Therefore, after making any changes in the setting of R11, repeat step (d). If R12 is readjusted, repeat steps (e) and (f).

- (g) If the range of R12 is not great enough to complete step (d) the total resistance of R5 and R6 must be modified. If the meter pointer remains to the right side of "0" when R12 is completely counterclockwise reduce the total resistance of R5 and R6. If the meter pointer remains to the left side of "0" when R12 is completely clockwise, increase the total resistance of R5 and R6. Make changes in increments of about 50K ohms, which is equal to half of the span of trimmer R12.

After correcting the total of R5 and R6 so that R12 is effective, make the adjustments of steps (d) through (f).

MAINTENANCE (CONT'D.)

8. COMPENSATING FOR LONG-TERM DETECTOR DRIFT (72-312 SERIES)

It may be necessary to readjust the amplifier zero balance circuit to compensate for long term drift changes beyond the range of the ZERO ADJ control. If the meter pointer cannot be adjusted to "0" and the batteries are known to be good, remove the panel assembly from the case and proceed as follows:

- (a) Set the function selector switch to MEAS X.1.
- (b) With the DET key up, rotate the ZERO ADJ control through its full range while observing the meter pointer. The pointer should normally deflect approximately the same amount in both directions. If deflection is off scale, use the MEAS X1 range.
 - (1) If the deflection range of the pointer is offset to the right side of "0" the total resistance of the amplifier resistors $R_X + R_X^1$ must be increased or the total of $R_Y + R_Y^1$ must be decreased.
 - (2) If the pointer range is offset to the left of "0" the total resistance of $R_Y + R_Y^1$ must be decreased or the total of $R_X + R_X^1$ must be increased.
- (c) Remove the three screws which secure the amplifier assembly and carefully roll it back so that the circuit side of the printed circuit board is exposed. Locate the resistors R_X , R_X^1 , R_Y , and R_Y^1 by the printed circuit board markings.
- (d) Change these resistance values using metal film resistors as required to give approximately equal meter deflection on either side of "0". A decade resistance box is helpful in determining the exact value required before permanently installing resistors.

9. METER REPLACEMENT

- (a) Meter failure usually occurs by suspension breakage due to severe shock. It is indicated by the failure of the meter to deflect when an unbalance is known to exist.

MAINTENANCE (CONT'D.)

- (b) To replace meter, remove panel from case as outlined in Section G-3. Disconnect the wires from meter terminals, noting the connections. Remove the ring nut or four machine nuts holding meter in place and lift meter out of panel. Remove jumper (short) from terminals of new meter and install meter following reverse of above procedure.

10. CALIBRATION

A screwdriver-adjusted rheostat, R7, located on the constant voltage PC board permits the reference voltage to be readjusted to compensate for long-term drift. This should be checked, and adjusted if necessary, on a regular schedule of once or twice a year. This calibration requires a voltage reference of approximately 1.02 volts such as the Biddle Compact Voltage Reference Standard Cat. No. 72-610. A standard cell or other equivalent may also be used. (The 72-610 Standard is superior to standard cells in that it can be carried to field or shop for calibration checks; it is pocket size, requires no special care in transportation, and retains its accuracy in spite of temperature variations). The reference source should be maintained at an accuracy of $\pm 0.005\%$.

To check and adjust this calibration, proceed as follows:

Connect the Standard to the emf binding posts (A or B) of the potentiometer and set the binding post selector switch to the corresponding position. Set the Function Selector switch to the 1V + POS RDG position and measure the value of the Standard; if a standard cell is used, follow the procedure of Section F-6. Adjust R7 as required to make the potentiometer reading agree with the value of the Standard.

Full calibration checks should also be made from time to time on instruments in heavy use. The interval may vary from one year to three years. These checks can be made with a 5-dial or 6-dial potentiometer of suitable range and accuracy. The Biddle Cat. No. 71-311 6-dial laboratory potentiometer is ideal for this application. The Cat. No. 72-3110 and 72-3112 high-resolution portable potentiometers can also be used. If such a check shows that adjustments should be made, the instrument should be returned to the factory.

SECTION H

FIELD REPLACEABLE PARTS LIST

<u>QUANTITY</u>	<u>DESCRIPTION</u>	<u>JGB PART NO.</u>
1	Meter	13440
4	Binding Posts (Superior #DF31BC)	11166-2
1	Knob, Modified, Slide-wire	13143
1	Knob, Function Switch (Buckeye PS-70PL-2)	4690-8
1	Knob, Compensator (Buckeye PS-70D-2)	4690-9
1 (72-310)	Knob, measuring dial	13438
1 (72-312)	Knob, measuring dial	13437
1	Knob, Zero Adj. (Stockwell Rubber Co. #LC9250-1)	11868
1	Pushkey Switch, DET (S2)	11357-3
1	Pushkey Switch, A or B (S3)	11357-4
1	Toggle Switch, Comp. Cct. (S5)	12119-3
1	Switch, function (S1)	13379-15
1 (72-310)	Switch, measuring dial (S4)	13379-16
1 (72-312)	Switch, measuring dial (S4)	13443
1	Potentiometer, compensator (R25)	13383-1
1 (72-310)	Potentiometer, zero control (R29)	11507-16
1 (72-312)	Potentiometer, zero control (R29)	11507-9
2	9V Battery, Null Det. Amp (BT1, 2) (Eveready #216-NEDA-1604)	1482
2	9V Battery, Measuring Circuit (BT3,4) (Eveready #266-NEDA 1605)	13045
1	1.5V Battery, Compensator ("C" Cell)BT5)	4376
1 (72-310)	Amplifier Assembly	13370-1
1 (72-312)	Amplifier Assembly	13353-1
1 (72-310)	Constant Voltage Supply Ass'y.	13220-1
1 (72-312)	Constant Voltage Supply Ass'y.	13220-7
1	Case Bottom	10998
1 (310-05, 312-01)	Case Lid with compartment	10997-1
1 (310-06, 312-02)	Case Lid, deep; holds Run-Up Box	10997-2
1 (310-09, 312-03)	Case Lid, deep, holds Versabuffer	10997-6

For replacement of parts not listed, return to factory.

ACCESSORIES

-	Calibration Voltage Standard, 1.01930V	Cat. No. 72-610
-	Measurement Accessories	See list, page 1

SECTION I

WARRANTY & REPAIRS

WARRANTY

All products supplied by the James G. Biddle Co. are warranted against all defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair will be shipped Prepaid and Insured. The warranty does not include batteries, lamps or tubes, where the original manufacturer's warranty shall apply. WE MAKE NO OTHER WARRANTY.

The warranty is void in the event of abuse or failure by the customer to perform specified maintenance as indicated in the manual.

REPAIRS

The James G. Biddle Co. maintains a complete instrument repair service. Should this instrument ever require repairs, we recommend it be returned to the factory for repair by our instrument specialists. When returning instruments for repairs, either in or out of warranty, they should be shipped Prepaid and Insured, and marked for the attention of the Instrument Service Manager.

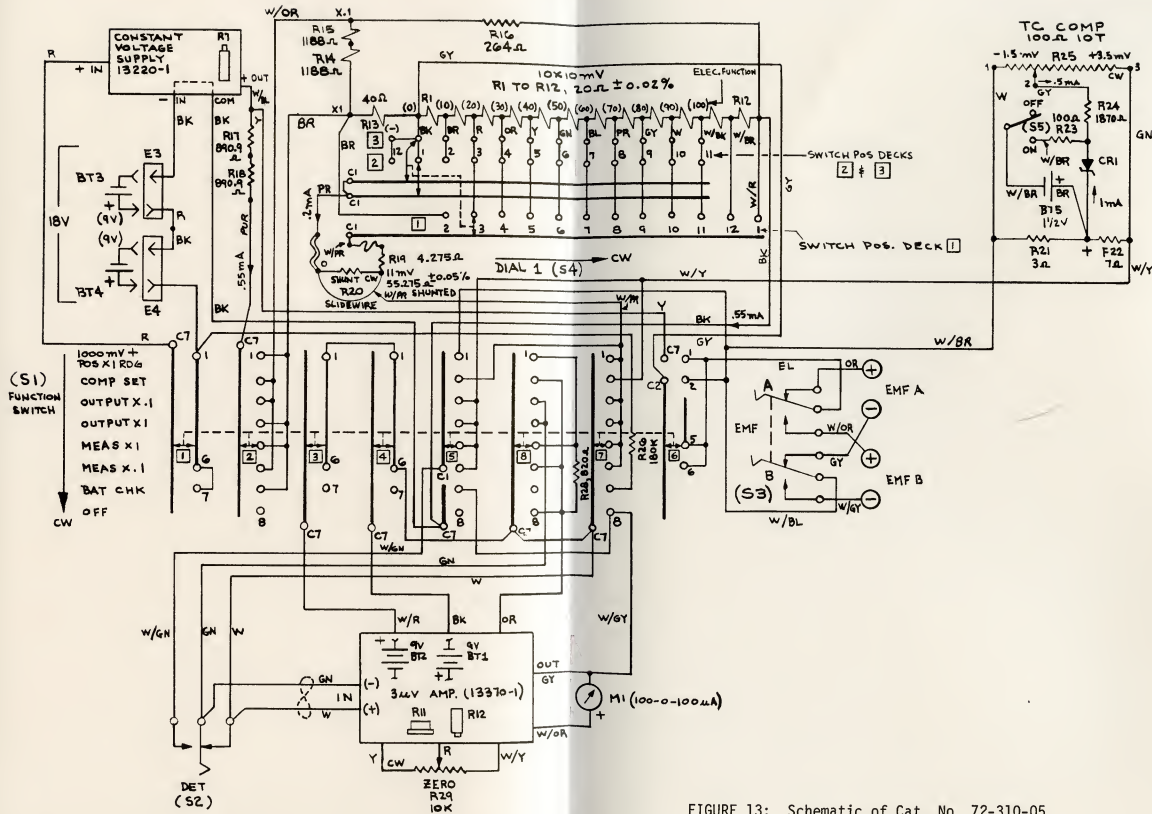


FIGURE 13: Schematic of Cat. No. 72-310-05

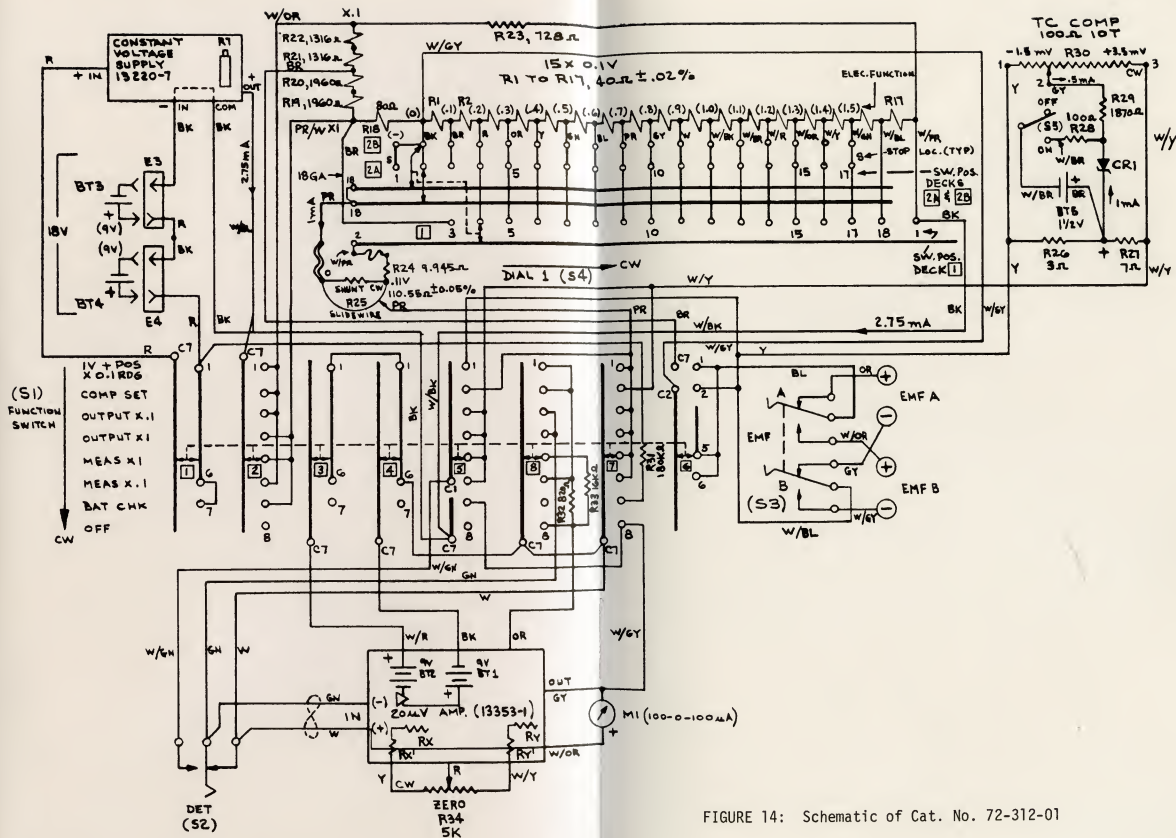


FIGURE 14: Schematic of Cat. No. 72-312-01



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